VALUES OF ECOSYSTEM SERVICES: OXYGEN PRODUCTION IN THE FORESTS OF BELGRADE

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Abstract

Forests produce oxygen, which is necessary for human existence, and bind CO_2, thus contributing to the reduction of global warming. Precisely forest biomass is the basic parameter in evaluating the amount of produced oxygen and bound carbon. In the past 50 years, more oxygen has been used, expressed in percentage, than in the entire Anthropocene. The reduction of oxygen, in the late 21st century, may become one of the dominant problems for the survival of life on Earth. With the annual oxygen consumption of only 10 billion tonnes, the human race would face danger in 100,000 years, with high concentrations of carbon dioxide at the same time. With an increase in oxygen consumption by 1.1%, this kind of danger would appear in 700 years. Different methods were used in identifying the cost of human life (use of resources, statistical methods, methods of determining human capital, questionnaires, etc.). The cost of a human life in the UK is estimated at EUR 3.1 million, in Latvia - EUR 320,000, in Luxembourg – USD 5.0 million, in Sweden - EUR 2.6 million and in Portugal - EUR 2.3 million. The cost of human life is determined based on age, sex, educational level, acquired qualification and social status. By using the known statistical data and adopting relevant methodologies, we have assessed that a human life in Serbia is worth EUR 368,000 (based on data for the second quarter of 2021). The total value of oxygen produced in the forests of Belgrade amounts to EUR 703,223 million and provides life for 1,910,954 inhabitants. According to the data of the Statistical Office of the Republic of Serbia, Belgrade had 1,694,056 inhabitants in 2019, which means that the existing forest ecosystems meet the current needs of the population. However, if we include other "consumers" of oxygen (cars, industry, etc.), we can conclude that the amount of oxygen produced in the forests of Belgrade is insufficient.

Key words: *ecosystem services, forest, oxygen production, value of human life*

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Introduction

Forests are exposed to a large number of negative effects that are reflected in the deterioration of their health condition, changes in the natural structure of stands, reduced area and the creation of conditions of ecosystem instability, incorrect management system and natural conditions in the form of climate change, acid rains, fires, etc. Climate change resulting from the increase in the concentration of greenhouse gases (CO_2, methane, chlorofluorocarbon, nitrous oxide and ozone) has an impact on the increase in air temperature, on a global level, by 2°C during the next 100 years (Bateman et Lovett, 2000).

Projections from the EURO-CORDEX initiative suggest that European land areas will warm faster on average than global land areas in the range of 1 to 4.5 °C for the RCP4. 5 scenario and in the range of 2.5 to 5.5 °C for RCP8.5 by the end of the century (Jacob et al., 2014), while the number of heat waves will be increasing by the end of the century (and as often as every two years in the second half of the 21st century) for the RCP8.5 scenario (EEA, 2016). In line with the increase in average annual temperature, precipitation is expected to increase by up to 25% in central and northern Europe, while a significant decrease is expected in southern Europe. By the end of the century, extreme daily precipitation will decrease by up to 25% in some parts of southern Europe, while it will increase by the same percentage in central and eastern Europe (Jacob et al., 2014).

Current climate change projections for Serbia foresee a trend of temperature increase for the A1B and A2 scenarios, for the three observed periods (2011-2040, 2041-2070 and 2071-2100) (MAFWM, 2015). The following temperature changes are expected for the observed periods:

1. 2011-2040 - 0.5-0.9°C temperature increase for the A1B scenario and 0.3-0,7°C for the A2 scenario;
2. 2041-2070 – 1.8-2.2°C temperature increase for the A1B and 1.6-2.0°C for the A2 scenario;
3. 2071-2100 – 3.6-4.0°C temperature increase for the A1B and 3.2-3.6°C for the A2 scenario.

The highest warming levels, exceeding 4.0°C by the end of the century, are expected to happen in the summer and autumn seasons (MAFWM, 2015).

Summer warming in the Balkans and western Turkey will be 5-6°C for the period 2071-2100 and the A2 scenario (Gao & Giorgi, 2008). Applying the ICTP-RegCM3 model for the period 2071-2100 and the A2 scenario, an increase of 7.0°C is predicted over the Balkan countries, including Serbia (Önol & Semazzi, 2009).

The amount of oxygen in the air decreases as a result of the increased concentration of CO_2 due to the increase in the use of fossil fuels, but also the use of wood from the forest ecosystems as an energy source. Population growth (today there are already 8,000,000,000 people) indicates an increasing need of the population for oxygen and clean air (Novak et al., 2002), which can only be provided from forest areas, especially urban forests around large city centres. For this reason, oxygen production is included in the ecosystem service in *Section*: Maintenance, *Sector*: Maintenance of Physical, Chemical and Biological Conditions.

Methodology

For the purpose of this paper, we used the data from the management plans of all the managing entities in the Belgrade area, as well as the areas under privately-owned forests.

The research area has been divided into 11 types based on the Typology of Belgrade Landscapes for the needs of the implementation of the European Landscape Convention (Cvejić i sar., 2008):

- Type 1: Alluvial plains of Pančevački Rit (divided into two sub-types: 1/1 - forests in the unprotected part (foreland) and 1/2 - forests in the protected part
- Type 2: Loess and loess plain of South Srem
- Type 3: Alluvial plain of South Srem
- Type 4: Alluvial landscapes
- Tip 5: Alluvial plain in the zone of Posavo-Tamnava and the lower reaches of the Kolubara river
- Type 6: Alluvial plain of the middle reaches of the Kolubara river and the Ljig river valley

- Type 7: Upland and plains in the immediate basin of the Sava river
- Type 8: Neogene upland in the Kolubara river basin
- Type 9: Hilly and hilly-mountainous landscape of northern Šumadija
- Type 10: Upland and plains in the immediate basin of the Danube river and in the basins of Ralja and Lug rivers
- Type 11: The Danube coast - sloping part of the right bank of the Danube;

The state of the growing stock was analysed by landscape type based on the data of forest estates. In the forest estate that included two or more types of landscape, adequate recalculation (transferring) of data into the corresponding type was performed.

The spatial database included the information on surface, tree varieties, canopy, mixture, life cycle, age classes, volume and volume increment.

The geographic information system (GIS), which allows a spatial analysis and a spatial presentation of biomass, was used to estimate the amount of bound carbon and produced oxygen in the area.

The results of oxygen production for the years 2030, 2050 and 2100 are presented for three scenarios: if there is no forest increment, if there is a 10% forest increment and if there is a 30% forest increment. For the year 2100, we show only data for the scenario where there is no increment due to the increased concentration of carbon dioxide resulting from the concept of civilization development aimed at achieving carbon neutral development by 2050.

The value of the amount of oxygen produced in the forests in the Belgrade area was estimated based on the estimation of the cost of human life, bearing in mind that oxygen is the basis of a healthy life and life in general.

Research findings

The industrial revolution brought a lot of air pollution. In the last 100 years, 245 billion tonnes of oxygen were destroyed and the atmosphere was polluted with 360 billion tonnes of carbon dioxide. Oxygen starvation is expected to occur if the current rate of oxygen consumption continues.

In the past 50 years, more oxygen has been used, expressed in percentage, than in the entire Anthropocene. The reduction of oxygen, in the late 21st century, may become one of the dominant problems for the survival of life on Earth. With the annual oxygen consumption of only 10 billion tonnes, the human race would face danger in 100,000 years, with high concentrations of carbon dioxide at the same time. With an increase in oxygen consumption by 1.1%, this kind of danger would appear in 700 years. This upward trend has already been reached, and industry uses 10% of oxygen produced by plants (Zahar, D.,1984, according to Velašević, V., 1998).

In the process of photosynthesis, plants bind carbon dioxide and release oxygen, and forest ecosystems are the most important for oxygen production. As much as 60% of the oxygen on Earth is produced by plants, while the rest comes from phytoplankton and water vapour that is created in the upper layers of the atmosphere. To create 1 tonne of primary organic production, the forest releases from 1.2 to 1.38 tonnes of oxygen. Plant life from an area larger than one hectare consumes 8 kg of CO_2 from the air in one hour, which is the amount exhaled into the atmosphere by 200 people (Bunuševac, T., 1973).

The balance between the amount of carbon dioxide and oxygen is of crucial importance for the living world on Earth. Although there is no reliable proof, we can still conclude that a small increase in the carbon dioxide content of plants increases the assimilation processes and leads to stabilisation. A small increase in the CO_2 content has influenced a volume increment of 10-30% in forests, while the impact, which would arise from a larger disturbance of the ratio, is unknown.

In the rebalancing of oxygen and carbon dioxide, there is usually a local deviation from the optimal ratio in the atmosphere. These differences are equalised from the resources of other areas by air currents. However, the reduction of oxygen is evident on a global level. For example, plants in the USA replace only 60% of the oxygen that is consumed annually by burning oil, coal and natural gas (Velašević, V. i sar., 1998).

Trees release oxygen when they use the energy of sunlight to make glucose from carbon dioxide and water. Oxygen is also used in the breakdown of glucose to release energy for the metabolic process. More oxygen is produced for these processes on average, during 24 hours, than the consumed amount. It takes six molecules of CO_2 to produce one molecule of glucose in photosynthesis. A molecule of glucose contains six carbon atoms, and a tree gets a net addition of one molecule of oxygen for each carbon atom. A tree about 15 meters high and weighing two tonnes (including roots and leaves) annually produces about 100 kilograms of wood, which includes 38 kilograms of carbon. In relation to the relative molecular masses of carbon and oxygen, it amounts to 100 kilograms per tree per year. A person inhales about 9.5 tonnes of air, but oxygen is only 23% of that air, and with each breath we separate slightly more than a third of oxygen, which amounts to 740 kilograms per year. That is approximately seven to eight trees. Oxygen production in total biomass (t ha^{-1}) is shown in Table 1.

Table 1. *Oxygen production in total biomass (t ha^{-1})*

Type of landscape	2020	2030			2050			2100
		Scenario			Scenario			
		0%	+10%	+30%	0%	+10%	+30%	0%
Type 1/11/1	462042	496664	534749	541673	790954	829039	835963	1137178
Type 1/2	185921	194014	202917	204536	262808	271711	273330	343742
Type 2	268589	277914	288173	290038	357184	367443	369308	450443
Type 3	331197	341943	353765	355914	433289	445110	447260	540755
Type 4	70635	72897	75384	75837	92119	94606	95059	114733
Type 5	170296	178884	188331	190049	251885	261332	263049	337768
Type 6	128605	133988	139909	140986	179743	185665	186741	233574
Type 7	490786	513532	538553	543103	706877	731899	736448	934342
Type 8	195738	206256	217825	219929	295658	307228	309331	400837
Type 9	1902822	1988564	2082881	2100030	2717375	2811691	2828840	3574799
Type 10	623826	655683	690727	697098	926474	961517	967888	1245050
Type 11	103136	107275	111829	112656	142460	147014	147841	183854
Total	4933591	5167616	5425043	5471848	7156827	7414254	7461059	9497074

Source: Original

We have valued the production of oxygen through the value of human life. Valuing life is a very difficult issue, often considered unethical, because human life is considered priceless. In the economic sense, the value of human life is always finite, because any rational decision-making mechanism must be able to weigh the probability of profit in relation to the probability of saving life (Vrijling and Galder, 2000).

"If, despite ethical problems, the cost of human life must be calculated, the objective number is the present value of the net product per capita of the country under study (Net National Product - Depreciation). For the Netherlands area, and a human lifespan of 70 years, the value is from USD 450,000 to 800,000, depending on the interest rate. The consequence of this approach is that the value of human life in developing countries is lower. This question seems strange and unethical, but highlights the advantages in the context of the national economy" (Vrijling and Galder, 2000). In ancient Egypt the price of slaves was about USD 32,000; in the Roman Empire a gladiator (slave) was worth USD 2,080, in America a boy (slave) was worth USD 8,100.

Different methods were used in identifying the cost of human life (use of resources, statistical methods, methods of determining human capital, questionnaires, etc.). The cost of a human life in the UK is estimated at EUR 3.1 million, in Latvia - EUR 320,000, in Luxembourg – USD 5.0 million, in Sweden - EUR 2.6 million and in Portugal - EUR 2.3 million. The cost of human life is determined based on age, sex, educational level, acquired qualification and social status.

The US Environmental Protection Agency, in 2011, put the value of a human life at USD 9.1 million, while the Food and Drug Administration estimated it to be worth USD 7.9 million. By using the known statistical data and adopting relevant methodologies, we have assessed that a human life in Serbia is worth EUR 367,996 (based on data for the second quarter of 2021).

We are aware of the fact that these data can help in recognising the importance of the forest for sustaining life, but also raise a number of other questions. If one human life is valuable, how much would one have to pay to prevent an event that in 100 or 500 years would result in the loss of tens of billions of human lives? If we use a 7% discount rate, the value is extremely small (USD 162.63), while at lower discount rates it is "so large that there are too many zeros to fit on this side" (Partnoy, 2012). The total value of oxygen produced in the forests of Belgrade amounts to EUR 703,223 million (RSD 82,628,752.81 million) and provides life for 1,910,954 inhabitants (Table 2).

According to the data of the Statistical Office of the Republic of Serbia, Belgrade had 1,694,056 inhabitants in 2019, which means that the existing forest ecosystems meet the current needs of the population. However, if we include other "consumers" of oxygen (cars, industry, etc.), we can conclude that the amount of oxygen produced in the forests of Belgrade is insufficient.

The Strategy of the Belgrade area afforestation (Ratknić, M. et al., 2009) foresees the afforestation of new 50,000 hectares (Option 1) to 100,342 hectares (Option 2), which should enable an increase in the bound carbon and the amount of oxygen produced. The increase in oxygen would be 100% under Option 1 to 200% under Option 2, based on urban forest oxygen production in

2021. Tables 3 and 4 show the expected risk foreseen for oxygen production under the climate scenarios A1B and A2.

Table 2. *Value of forest ecosystems expressed in the cost of human life*

Type of land-scape	Total number of trees	Number of trees needed for life	Number of inhabitants provided with oxy-gen	Cost of a hu-man life	Total value of produced oxygen (in million RSD)
Type 1/1	493486	8	61686	43,239,530.00	2,667,273.65
Type 1/2	412006	8	51501	43,239,530.00	2,226,879.03
Type 2	311713	8	38964	43,239,530.00	1,684,785.05
Type 3	360595	8	45074	43,239,530.00	1,948,978.58
Type 4	73718	8	9215	43,239,530.00	398,452.27
Type 5	185885	8	23236	43,239,530.00	1,004,713.72
Type 6	95671	8	11959	43,239,530.00	517,101.54
Type 7	1799480	8	224935	43,239,530.00	9,726,083.68
Type 8	3591959	8	448995	43,239,530.00	19,414,332.77
Type 9	7334608	8	916826	43,239,530.00	39,643,125.33
Type 10	49771	8	6221	43,239,530.00	268,993.12
Type 11	578738	8	72342	43,239,530.00	3,128,034.08
Total	15287630	8	1910954	43,239,530.00	82,628,752.81

Source: Original

Table 3. *Expected risk for ES - production of oxygen caused by climate change by applying the A1B Model*

Risk	Spring	Summer	Autumn	Winter
Heat wave	**Very high**	**Very high**	High	
Extreme cold	High			*Medium*
Drought	**Very high**	**Very high**	**Very high**	
Heavy precip-itation / flood-ing	High	High	*Medium*	
Storms	High	High	High	High

Source: Original

Table 4. *Expected risk for ES - production of oxygen caused by climate change by applying the A2 Model*

Risk	Spring	Summer	Autumn	Winter
Heat wave	**Very high**	**Very high**	**Very high**	
Extreme cold	High			High
Drought	**Very high**	**Very high**	**Very high**	
Heavy precipitation / flooding	**Very high**	**Very high**	High	
Storms	**Very high**	**Very high**	**Very high**	**Very high**

Source: Original

The following risks have the greatest impact on forest ecosystems: heat wave, extreme cold, drought, heavy precipitation/floods and storms. Each of these risks has a different frequency in the analysed scenarios and is given by season.

Conclusions

Forests play a decisive role in the production of oxygen, which is necessary for human life, and by accumulating carbon, they influence the reduction of the effect of global warming. By absorbing CO_2 from the air, they turn it into biomass, and release oxygen into the atmosphere, which means that these processes are an important segment of the ecosystem services that forests provide in terms of improving air quality.

The existing urban forest ecosystems in the area of Belgrade meet the current needs of the population, but if we include other "consumers" of oxygen (cars, industry, etc.), we can conclude that the amount of oxygen produced in the forests of Belgrade is insufficient. This indicates the need to plant new forests in the future to compensate for this shortage of oxygen.

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